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ABSTRACT

This report of an international workshop contains recommended guidelines on marine science teaching and training at the first degree level, equated here with a Bachelor of Science, except in those countries in which the first degree corresponds to a Master of Science or its equivalent. Three instructional models are presented: the first model for a minimal program, the second one leading to a first degree with marine science emphasis, and the third one leading to a first degree in marine science. The report includes discussions on necessary and desirable requirements, in terms of human resources and physical facilities, and on the need for practical experience and curriculum assessment. It further gives recommendations for introducing and strengthening first degree marine science in general. The appendixes provide selected workshop presentations that exemplify the development, nature, and diversity of first degree marine science programs in six countries: Brazil; China; Tanzania; Thailand; USSR; and the United States. The appendixes also includes a list of participants (13 experts from 13 countries); a marine science activity course matrix; and a bibliography. (TW)

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Marine science teaching and training at first degree (undergraduate) level

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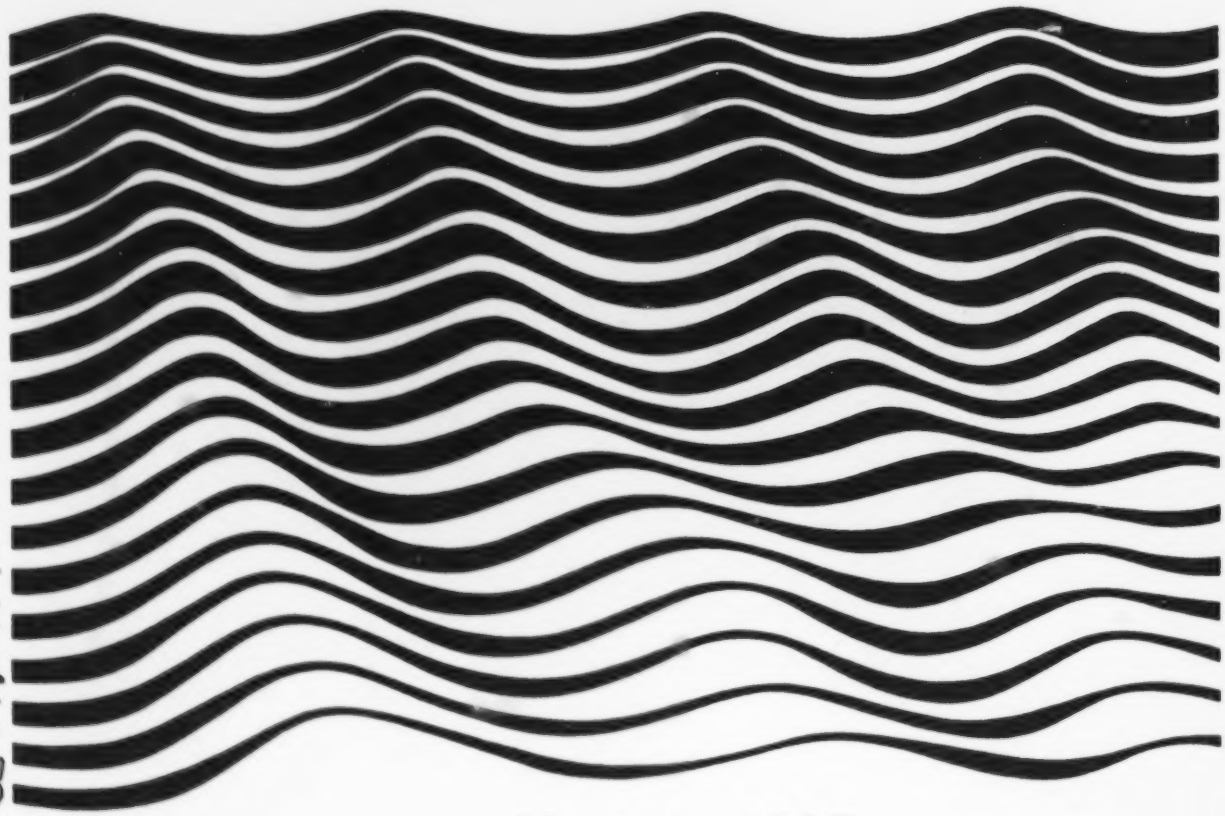

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38	Marine Sciences in CMEA countries Programme and results of co-operation Available in English and Russian	1986
39	Development of marine sciences in Arab Universities Meeting of Experts held at the Marine Science Station Aqaba, Jordan 1-5 December 1985 Available in Arabic, English, French	1986

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Marine science teaching and training at first degree (undergraduate) level

Recommended guidelines from a Unesco workshop on university curricula

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PREFACE

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ABSTRACT

This report contains recommended guidelines on marine science teaching and training at the first degree level, equated here with a Bachelor of Science, except in those countries in which the first degree corresponds to a Master of Science or its equivalent. The report was prepared by participants attending an international workshop held at Unesco, Paris from 17 to 21 November, 1986.

Three instructional models are presented: the first one for a minimal programme, the second one leading to a first degree with marine science emphasis, and the third one leading to a first degree in marine science. The report includes discussions on necessary and desirable requirements, in terms of human resources and physical facilities, and on the need for practical experience and curriculum assessment. It further gives recommendations for introducing and strengthening first degree marine science in general.

This workshop was the sixth in a series of Unesco-sponsored workshops aimed at providing guidelines for the establishment and reinforcement of teaching and training in marine science and related fields at different educational levels.

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I. EXECUTIVE SUMMARY AND RECOMMENDATIONS

The purpose of this workshop, attended by 13 experts from 13 countries, was to consider the implications of the global extent of marine science teaching and training at the first degree (undergraduate) level, and to provide guidelines accordingly. The term "first degree" is here defined as a B.Sc. degree or its equivalent, except in those countries in which first degree corresponds to a M.Sc. degree or its equivalent. Chapter II of this report summarizes the rationale and organizational details of the meeting, which included the commissioning by Unesco of a survey of first degree marine science curricula throughout the world. Together with reviewers' comments, the results of this survey were used as the principal input documentation for the workshop. The workshop considered "marine science" to be the traditional fields of oceanography, although it was recognized that other fields of marine-related science and technology which includes ocean engineering, etc. also have oceanographic teaching and training at the first degree level.

Chapter III briefly reviews some of the main conclusions of the global survey report. The document identified 95 institutions in 44 countries having some sort of undergraduate marine science or closely related instructional programme, which conclusively demonstrated the importance placed, in both countries with limited and advanced marine science capabilities, on having these curricula. The difference in teaching approaches was found to vary from universities offering only a course within a basic science curriculum, usually biology, to universities offering an extensive range of courses culminating in a marine science degree. To illustrate the development, nature and diversity of the instructional programmes, the following six examples from workshop presentations were selected for inclusion in Annex II: Brazil, China, Tanzania, Thailand, Union of Soviet Socialist Republics and United States of America.

Chapter IV provides a background of first degree marine science curricula. The reasons for teaching these curricula are threefold: (1) to enhance knowledge about the oceans among the educated populace, (2) to provide trained technical support staff for ocean studies, and (3) to create a core of persons who, after additional higher level training, are equipped to carry out basic and applied marine research. The workshop did not consider graduates from first degree programmes sufficiently equipped to carry out independent research. It was noted that undergraduate marine science instruction is highly diverse and dependent primarily on the level in each country of marine sciences research and activities utilizing ocean resources. Three developmental stages were recognized, each of which had distinctive indicators. Although there are many potential job opportunities, it was found in general that the government and universities were the primary employers in many countries. The number and type of jobs appeared to be related to the national economy and the importance of marine science within a country. Three co-operative activities were identified by the workshop participants that could locally, regionally and inter-regionally facilitate undergraduate teaching and training: (1) exchange of teachers and students, (2) joint research programmes with opportunities for undergraduate students to participate, and (3) visitation on ships of opportunity.

Chapter V is on guidelines to curriculum development. Since it was recognized that no one system of offering marine science was suitable for all universities, three different models were proposed: Model I for a minimal programme, Model II leading to a B.Sc. degree or its equivalent having a marine science emphasis, and Model III leading to a B.Sc. or its equivalent in marine science. An institutional infrastructure appropriate for each model is also proposed. For Models I and II, each principal discipline of marine science should be represented by at least one faculty member who does not necessarily need to be full time in the marine science programme. Model III would require several full-time marine scientists. Proposed facilities and resources include a library and computers, as well as types of ships and shore-based laboratories that could or should be utilized. A minimum introductory field experience is cited together with the equipment to support it. The types of teaching materials expected to be in an available collection are listed. The general aspects of marine academic research and the need for practical experience in all three models are discussed. Finally, suggestions are made on how a curriculum could be assessed using feedback from students who have graduated and by other means.

Recommendations

The workshop participants unanimously adopted a number of recommendations. The first five concern in-country arrangements for the establishment and strengthening of first degree marine science teaching and training. They are applicable to concerned educational institutions, as well as governmental and private organizations. The last two recommendations are directed to Unesco for assistance in corresponding national endeavours and to Unesco and other international organizations for supporting relevant co-operative programmes.

1. Recognizing the increasing need of well-trained manpower as a prerequisite for studying the marine environment, rational utilization of its resources, and for its protection, it is recommended that countries which have insufficient marine science capabilities, examine the desirability of introducing marine science teaching and training at the first university degree (B.Sc.) level to:

a) Enhance the pool of knowledge about the oceans among the educated populace,
b) Provide trained technical support staff for ocean studies, and
c) Provide a core of persons who, after additional training at a higher level, will carry out oceanographic research, taking into account that graduates from first degree programmes are not considered sufficiently equipped to carry out independent research in the marine sciences.

2. When designing first degree marine science teaching and training curricula, it is recommended that a country or university chooses a model most suited to local needs and resources. It is proposed, however, that for any marine science curriculum the first instruction be a multi-disciplinary introductory course including biological, chemical, geological and physical oceanography, which could be taken as early as in the second year of the curriculum.

3. It is recommended that ways and means should be sought locally to attract good science students to marine science studies Mechanisms for accomplishment might include:

a) Information provided to the general public through news media, films, lectures, visits to aquaria and coastal stations,
b) Introduction of marine science elements into the existing secondary school curricula,
c) Information about marine science disciplines, curricula and careers provided to university science students through counselling,
d) Provision of fellowships for post-graduate training in marine science for the best students who have completed their first degree marine science curriculum.

4. Recognizing the importance of a good grounding in basic sciences as a prerequisite to beginning a marine science curriculum, it is recommended that universities initiating marine science teaching, assure that students obtain a sound background in basic science subjects, with particular emphasis on mathematics (including computer programming and statistics), physics and chemistry, before starting their studies in marine science. In addition, students should obtain, wherever possible, practical training in a laboratory, on field trips and at sea, either through the university's own resources or in co-operation with other institutions.

5. It is recommended that universities, government and private organizations keep in close contact to exchange information about needs for trained manpower and job opportunities for first degree marine science candidates.

6. It is recommended that Unesco provides assistance to countries wishing to introduce or expand first degree marine science at their universities, through:

a) Information regarding curriculum design, teaching materials, etc.,
b) Training courses,
c) Encouraging the provision from extra-budgetary funding sources of fellowships for B.Sc. graduates to obtain higher-degree training, in particular for those universities having only first degree marine science programmes,
d) Provision of advisory services.

7. It is recommended that countries consider the establishment of co-operative programmes for strengthening their marine science teaching and training. Such co-operation between countries within a region, and between those with limited and those with advanced marine science capabilities could include various means such as:

a) Regional training networks,
b) Access to research vessels and use of specialized equipment,
c) Exchange of teachers,
d) Curriculum development and assessment,
e) Exchange and dissemination of information, literature, teaching materials, etc.

It is furthermore recommended that Unesco and other international organizations, should provide resources, guidance and co-ordination to facilitate this co-operation.

II. INTRODUCTION

Unesco's first marine science curricula workshop dates back to 1973, and resulted in the document 'Marine Science Teaching at the University Level', published as Unesco Technical Report in Marine Science 19. Subsequent attention in the marine science curricula programme was given to syllabi for training marine technicians and for secondary schools, in which the Intergovernmental Oceanographic Commission took the lead, and to fisheries science and ocean engineering teaching at the university level. The recommended guidelines that resulted were published as Unesco Reports in Marine Science 4, 5, 15, 25 and 26, respectively.

The present workshop originates from Unesco's observation of the increasing involvement by universities in first degree or undergraduate marine science teaching and training programmes, and from Unesco's own involvement through requests for advice and teaching materials for such programmes from universities in countries developing their marine science capabilities. Such involvement does not easily correspond with one of the main conclusions of the above-mentioned 1973 workshop which recommended only a limited and elective role of marine science at the undergraduate level, leaving most, if not all, teaching and training in this discipline to students holding at least a B.Sc. degree or equivalent in one of the natural sciences.

To allow an appreciation of the extent and nature of marine science teaching and training at the first degree or undergraduate level, a global survey was commissioned to the Institute of Educational Technology of the Open University of the United Kingdom. A detailed questionnaire was sent out during late 1984 and early 1985 to about 320 institutions for tertiary education, mainly universities, in over 100 countries. Responses were finally received from 145 universities in 65 countries, of which 95 in 44 countries indicated that they offer either first degrees and/or substantial undergraduate instruction in one or more marine science fields.

The draft results from the survey were then sent for review to seventy selected persons worldwide, mainly in academia, but several also in relevant governmental organizations and industry. Their specialities covered the main marine science disciplines. Care was taken to include people who were likely to have widely different views on the topic. Comments were received from thirty-three reviewers and an analysis was made of their observations. The draft results from the global survey and the analysis of the reviewers' comments on the survey served as main working documents for the present workshop.

The present report gives the results of the Workshop on Marine Science Teaching and Training at First Degree (Undergraduate) Level held at Unesco, Paris, from 17 to 21 November 1986. Thirteen highly qualified experts of diverse specialities in marine science, and from different regions and working backgrounds, were invited to participate in the workshop (see Annex I). The presence in the workshop of the different opinions on the subject-matter, was given particular attention. The above-mentioned comments from reviewers provided the main source for selection in this respect.

In addition, three of the participants who had attended regional meetings on university marine science in general, reported the first degree-related results of those meetings to the present workshop. Their observations concerned meetings in the Arab Region (Aqaba, December 1985), in the Asia and Pacific Region (planning meeting in Bangkok, June 1986) and in the African Region (Nairobi, August 1986). (The results of the meeting in the Arab Region have been published as Unesco Reports in Marine Science 39).

The main objective of the present workshop was to prepare guidelines (favourable or restrictive) and recommendations on marine science and technology offerings at the first degree level based on discussions of a number of pertinent questions, in particular the following:

- What are or should be the main reasons and objectives of establishing marine science/technology teaching and training programmes taking into account societal, industrial, professional needs and priorities of countries at different developmental levels?

- Therein, what is or can be the role for marine science offerings at the first degree (undergraduate) level and does the role change as a country advances in marine science? If so, in what sense?

- How do university perceptions of this role relate to government policy in your country concerning, for instance, declaration of an Exclusive Economic Zone, marine fisheries, aquaculture, offshore oil and gas, coastal resources management, etc.?

- What is or should be the interdependency between first degree (undergraduate) marine science offerings and the level of basic sciences taught at (i) the university and (ii) the secondary school level?

- Would a clearer description of professional and technical jobs obtainable upon graduation, and inclusion of more marine and coastal themes in secondary school teaching help to attract more and better students in marine science and related fields?

- Who uses the graduates in your country, and are the supply and qualifications appropriate to the demand (for workshop participants from universities or countries where first degree (undergraduate) marine science curricula are offered)?

- Would more sub-regional, regional and inter-regional co-operation between universities in marine science teaching and training help to alleviate problems inherent to limitations in educational means and expertise in many parts of the world? If so, how best to promote or organize such co-operation?

The presentations and views by the participants on the above questions varied greatly as can be expected. However, the discussions revealed a consensus about the (potential) role of marine science offerings at the first degree level, especially when seen in the perspective of curricula that evolve with the marine scientific requirements and possibilities in a particular country or university.

The present report reflects that consensus and gives the guidelines and recommendations prepared on the basis thereof by the workshop. These results would not have been possible without the fine and diligent efforts of the participants. The global survey carried out by Mrs. B. Swift of the U.K. Open University proved invaluable as a reference for the workshop.

A first degree may vary considerably from one country to another and even within the same country, both with respect to duration and substance as well as university entrance requirements. The term 'first degree' as used in the present report refers to - unless stated otherwise - a B.Sc. degree or equivalent, except in those countries in which the first degree corresponds to a M.Sc. degree or equivalent. The undergraduate curriculum is defined as the set of knowledge, skills and attitudes to be imparted to students for such degrees as well as the educational activities to achieve this. Those studying for the first degree are referred to as undergraduates and as graduates after obtaining it. Under higher degree studies are understood those leading to M.Sc., Ph.D. and equivalent degrees. For information on both the systems, and the stages of higer education in 141 countries, reference is made to 'World Guide to Higher Education. A comparative survey of systems, degrees and qualifications', 2nd ed., published by Unesco, Paris, 1982.

For general definitions of marine science disciplines, one is referred to the afore-mentioned 1973 workshop report published as Unesco Technical Paper in Marine Science 19. In a general sense, engineering is regarded as a branch of science. However, marine science and ocean engineering tend to be considered as separate but closely related, mutually supportive fields. The separate identification of the two fields should not obscure their interlinked continuity.

III. GLOBAL EXTENT OF FIRST DEGREE CURRICULA

Prior to the present workshop Unesco had commissioned a survey of first degree curricula in marine science on a global basis. The purpose of this survey was to collect information on the global spread of the practice since the publication of Unesco Technical Paper in Marine Science 19 in 1974. The survey also addressed itself to the nature of first degree offerings in marine science and related fields and the extent to which such offerings were degrees in marine science or degrees with marine science.

One hundred and forty-five (145) institutions responded to the survey and 95 of these in 44 countries indicated that they are now offering marine science in their first degree curriculum. The practice is clearly world-wide and not confined to any particular region or grouping of countries.

The majority of institutions offering marine science at first degree level have introduced it initially through the biological sciences and the majority of offerings are now in marine biology and biological oceanography. Nevertheless substantial offerings are available in chemical, geological and physical oceanography, and in a few countries (e.g. Argentina, China, Egypt, the U.S.A. and the U.K.) some institutions are offering first degrees in all four of the main disciplines. In some instances first degree programmes are being offered in applied marine science fields, e.g. ocean engineering or technology, fisheries, and mariculture.

The survey indicated a wide variety of different approaches to the teaching of marine science at the first degree level; there was not one common model. At the end of the spectrum were institutions which offered only a few courses within a basic science curriculum (degrees with marine science); at the other end of the spectrum were institutions which offered an extensive range of courses to provide a degree in marine science. In between these extremes were various models usually tailored to the capabilities of the institution and the needs of the local community. Institutional support for first degree programmes was usually provided by an individual department or by an interdisciplinary group of faculty members providing overall supervision of the programme.

The various degree programmes surveyed tended to focus on preparing students for a career in marine science or related activities, while at the same time ensuring that students continue to receive a solid grounding in the basic sciences. Many universities participating in the survey predicted an increased demand for graduates in the marine sciences, particularly in the fields of aquaculture, marine resources development and management, and environmental management and control. Although universities make such predictions, the number of students taking first degree instruction in marine science was relatively small, usually less than 30 in a course and often as low as 4 or 5. The survey report has documented the fact that marine science education at the first degree level is truly global.

To illustrate the nature and diversity of marine science offerings, six examples were prepared by workshop participants from different parts of the world. The breadth and depth of each example is different, reflecting regional differences, individual involvement and the specific development of marine science within the writer's country. These examples are presented in Annex II of this report.

IV. NATURE OF FIRST DEGREE PROGRAMMES

Reasons and Objectives

The utilization of marine resources demands a sound scientific and technological basis which can best be achieved by training local personnel. The importance of marine science teaching to national economic development cannot be over-emphasized.

In broad terms the rationale for teaching marine science at the undergraduate level can be stated as :

a) To enhance the pool of knowledge about the oceans, among the educated populace, so that decision makers, managers, teachers, etc. can understand its relevance to national goals, particularly the exploitation of marine resources, the management of the ocean environment and international affairs,

b) To provide trained technical support staff for ocean studies including resource management and environmental protection,

c) To provide a core of persons who, after additional training at a higher level, are equipped to carry out basic and applied research in the oceans.

These goals should be the same for all, especially coastal countries, but the manner in which they are achieved (i.e. the nature of the undergraduate programme) will differ according to the level of societal development and the availability of human and physical resources. In accordance with local needs, different countries, or different institutions within countries, may place emphasis on any one or all of these objectives, and the nature of the curriculum should vary according to where emphasis is required. We thus expect that undergraduate curricula will not be uniform in content at different institutions; there is a minimum core of knowledge which should be acquired through all such curricula. Outside of this core every institution should tailor its programmes according to local needs.

Roles at Different Stages

The role for marine science offerings at the undergraduate level is highly diverse and dependent mainly on the level of marine science research and activities utilizing ocean resources in a given country. The jobs available to graduates at the first degree level in marine science may vary from researcher to teacher and from manager to technical staff, as a country advances in marine sciences.

Successive stages can be distinguished in the recent process of marine science development. At an early stage when marine science and marine affairs are non-existent or very limited, no local marine science training can be offered. The limited number of the necessary experts with marine science knowledge are usually educated abroad in countries advanced in marine science.

At an intermediate state when a country starts to develop its own marine science and coastal or offshore activities, urgent needs appear for people with locally-provided marine science training. In consequence of the rapid development of marine resources exploitation and environmental protection, a great variety of positions in industry, government and academe up to university teacher or researcher, are available to graduates having first degrees with a marine science emphasis. Many of these jobs tend to be of a general rather than specialist nature.

The situation changes, however, as the level of marine science develops. At an advanced stage, when marine science is highly developed, the role of first degree training in marine science becomes more constrained and limited mainly to the preparation of specialized technical staff and research assistants, while academic and many managerial positions are offered only to graduates with higher degrees. Experience in certain countries has shown that, for postgraduate studies in marine sciences, a first degree in marine science does not necessarily have advantages over one in basic sciences.

It is important for a country developing its marine science capabilities to take this evolution into account, to realize the relevance and limitations of the first degree training and to orient its strategy in marine science education accordingly.

Job Opportunities and Curricula Adaptation

There are a great number of potential opportunities for work in studying the marine environment and the development and management of its resources. Many employment areas are listed in the left hand columns of the matrix given in Annex III, which couples marine research and management activities with training fields and subjects. The matrix originated from a regional planning meeting on marine science curricula in Asia and Pacific universities (Bangkok, June 1986). The present workshop considered such a matrix useful for counsellors and students in course selection. Its use in the Asia and Pacific region will be considered at a regional meeting in Qingdao, China, at the end of 1987.

While the government and universities in many countries are the primary employers of first degree graduates, there are also areas where private jobs can be obtained. However, the employment possibilities in a particular country, depend upon the national economy and the importance given to marine science related activities in the national development plans or concentration areas.

In addition to direct academic, industrial or government employment, a portion of the first degree graduates does and should continue for advanced studies. For countries developing marine science activities, this portion increases with the strengthening of marine science in the country. At the same time the major basis for the advanced training moves from abroad towards the home country.

Along the development of marine science related activities, the teaching and training programmes should be extended in order to cover new areas. This means a continuous process of identification of needs and corresponding adaptation of first degree curricula, as well as their consolidation to avoid the over-production of the early-day generalists. Lessons on this process cannot simply be drawn from experiences in countries with long traditions in marine science. This is because marine science development patterns in the past vary from present and future patterns due to different advances in science and to differences in societal, industrial and governmental circumstances.

Regional Co-operation

Limited resources, infrastructure, and indigenous expertise for marine science education make desirable a variety of mechanisms for subregional, regional and inter-regional co-operation, both bilateral and multilateral. The ocean itself recognizes no political boundaries, and in efforts to co-operate we must seek several common denominators or themes as criteria for defining the regions of co-operation. Such commonalities might include: geographic proximity, similarities of the ocean environment and/or climate, a common language, exploitation of the same fish stocks and exposure to pollution from the same or similar sources.

Several co-operative activities should be considered at the subregional, regional and inter-regional level to facilitate undergraduate training, such as the following :

- The exchange of personnel, especially teachers involved in undergraduate programmes;
- Joint research programmes with opportunities for participation by undergraduates, such as the compilation of a regional coastal resource inventory or a regional marine water-quality programme;
- Visits to research vessels and where possible shipboard training of undergraduates.

V. GUIDELINES FOR FIRST DEGREE INSTRUCTION

Introduction and Scope

After extensive discussions and analysis of the relative merits of the various approaches to first degree marine science education, the workshop participants recognized that no universal solution exists to address each nation's particular needs. Therefore three basic curriculum models are described. The discussions and recommendations are restricted to the field of marine science or oceanography as customarily defined to include the subfields of biological, chemical, geological, and physical oceanography. Degrees in fisheries, marine affairs, aquaculture, ocean engineering and other marine-related disciplines are not addressed. However, the importance of these fields is recognized, together with the fact that the needs of some countries and institutions may dictate the establishment of programmes in one or more of these related fields in preference to the ones detailed below. In these cases, it is recommended firstly to consider the findings and suggestions in the present report, in view of the many parallels between marine science and these other disciplines, and secondly to consult the appropriate Unesco reports which treat some of the related fields, e.g. Unesco Reports in Marine Science 4, 15, 25, 26.

The three curriculum models may be viewed in two perspectives. From the evolutionary perspective, one may consider a progression of development and maturation from Model I to Model III, viz. an institution with limited resources and/or one just embarking on an undergraduate marine science programme could start by slightly modifying and adding to existing traditional curricula in basic sciences. Next, this institution could 'mature' into offering Model II and then Model III as additional resources become available.

In the second perspective, each model can be considered as the mature expression of an institution's philosophy about undergraduate marine science education. Model I would then represent the philosophy that most education about the ocean should be deferred until after obtaining a B.Sc. or equivalent degree, and that those studying for a first degree should establish a solid foundation in a basic science, enhanced by one or two elective courses in marine science. Model II could be the ultimate design for schools which believe in a basic science with a 'minor' in marine science. Full exposure to marine coursework and research would be primarily during pursuit of higher degrees. Model III, in this perspective, would be for those institutions which believe that it is productive to teach multi- and inter-disciplinary marine science courses to undergraduates. We suggest that whenever practicable, it may be useful to incorporate marine subjects and examples into basic science courses. In contrast to Models I and II, where research is usually delayed until higher degree study, Model III undergraduates undertake research projects on ocean topics and write a thesis. The graduate with a B.Sc. or equivalent degree from any of the three Models could also continue for higher degree studies.

For a general description of the different marine science courses in the Models given below, one is referred to Unesco Technical Paper in Marine Science 19. For additional and updated course details, however, it is recommended to consult a specialist in the particular discipline or subject matter, if necessary through Unesco. In all three Models it is recommended that students should be required to have training in statistics and computing.

Model I: Start-up or minimal approach to first degree marine science education

Major: Biology, Chemistry, Geology, Mathematics or Physics

Basic Science Courses Required as Minimum Prerequisite Include:
Mathematics beyond Calculus
1 year Physics
1 year General Chemistry
If adequate preparation has not been acquired in Secondary School, then also: 1 term Biology and 1 term Earth Science

Elective: 1 term Introductory Oceanography Course
1 term Special Oceanography Course in Student's Major.

Model II: B.Sc. or equivalent degree with marine emphasis

Major: Biology, Chemistry, Geology, Mathematics or Physics.

Minimum Prequisite in Basic Sciences:
As from Model I
Required Marine Courses:
(a) Introductory Oceanography

(b) Four courses in one speciality:
Biological Oceanography
or Chemical Oceanography
or Geological Oceanography
or Physical Oceanography

Optional: Project and Thesis.

Model III: B.Sc. or equivalent degree in Marine Science

Major: Marine Science

Minimum Prerequisite in Basic Sciences:
As from Model I
Required Marine Courses:
(a) A selection of eight courses including one general course in each of the oceanographic disciplines (biological, chemical, geological and physical)
(b) Four specialist courses
(c) Project and Thesis.

Infrastructure

In an Institution offering Model I, it is recommended that the curriculum and teaching programme come under the supervision of a Marine Science Committee consisting of staff members of the relevant basic science departments as well as the marine science teachers associated with the programme. For this Model it will be necessary for the library to have basic reference texts in the marine science options offered as well as other reference materials.

Institutions offering Model II or III may need to set up a separate Unit or Department of Marine Science with its own budget. It may have separate teaching staff of its own or staff having joint appointments in basic science departments. This Unit/Department should be responsible for overseeing the teaching programme in marine science and ensuring the availability of equipment and services, including laboratory and sea-going facilities and technical support staff.

Faculty

University faculty in marine science should have a Ph.D. or M.Sc. degree in an appropriate discipline which included marine science training. They should have research experience and teaching proficiency.

For Model I curricula, at least one part-time faculty member should represent each main discipline of oceanography. One of them should be designated coordinator for the introductory oceanography course.

Model II curricula require for each of the four main disciplines of oceanography at least one full time senior faculty and another junior faculty member capable of teaching the courses being offered in marine science. Not all of them have to belong full-time to the Marine Science Programme, but they must be available for teaching and supervision.

For Model III curricula, a full time marine science faculty of at least 8 to 10 members representing the four main disciplines will be required.

Facilities and Resources

a) Library

A library is an essential resource facility in any training and academic institution. To ensure the availability of sufficient and appropriate literature to service marine science training programmes, it is recommended that institutions offering marine science programmes should, in addition to the university libraries, have as a minimum a technical or special library consisting of a reasonable collection of standard textbooks, relevant journals, other reference literature on

biological, chemical, geological and physical oceanography as well as pertinent audio-visual and computer-based information materials. It would be desirable for the library also to have literature on the related fields, such as fisheries, marine affairs, aquaculture, ocean engineering, etc. (Regional information centres, with assistance from Unesco and other agencies, are well placed to assist teachers in keeping abreast of significant new literature, and assist in making reprints/copies of this literature available to institutional libraries and through them to students).

b) Computers

Since marine sciences are concerned with acquiring, analyzing, and manipulating large quantities of data, special attention must be given to introduce students as thoroughly as possible to computer techniques for data processing and storage. Thanks to the development of computer technology, a large amount of processing may be accomplished on inexpensive personal computers. As an example from physical oceanography, it is noted that the algorithms published by Unesco for computation of fundamental properties of sea water (Unesco Technical Paper in Marine Science 44) may be programmed and computed on small 32k-memory microcomputers. These machines also provide valuable tools for data storage on cassette tapes or floppy discs. In addition, a student with computer skills can access computer communication networks, conduct literature searches and prepare reports using word processing and graphics software.

c) Vessel and Laboratory Requirements

Shipboard experience is an essential element of all marine science curricula in order for students to develop an appreciation for, and eventually master, the skills and techniques of oceanographic sampling. In all but rare cases, the dedication of a full-service, deep-sea research vessel to an undergraduate programme will be impossible. Therefore extensive use of ships of opportunity and small vessels will be required. These may come from companion graduate departments or research institutes at the same university, from other marine science agencies in the country or from abroad (visiting vessels). The ultimate experience would be offered by a vessel with equipment and laboratories as described in Unesco Technical Paper in Marine Science 19, pages 24-26. However, acceptable desired results could be obtained from field experiments on small vessels, skiffs or even a shore-based sampling exercise. A minimum introductory field experience would include the following:

i) water sampling with analysis for temperature, salinity, oxygen, pH, nutrients,
ii) currents and tide measurement and analysis,
iii) water tranparency and colour measurement and analysis,
iv) plankton collection and analysis,
v) sediment or substrate collection and analysis,
vi) meteorological measurements of temperature, humidity, barometric pressure and wind speed with analysis,
vii) recording of sampling in field notebook or log,
viii) data analysis and interpretation.

When ship time is available, the above exercise should utilize the following equipment: remotely closing water bottles with reversing thermometers, salinometer, echosounder, plankton net, bottom dredge, fish trawl, corer, current meter, transparency meter, irradiance meter, bathythermograph (mechanical and expendable), and shipboard navigation and positioning. Data analysis and sample processing can be completed in either a shore-based or shipboard laboratory equipped with:

a) desk computer and/or calculator,
b) measuring instruments for conductivity, temperature, pH, oxygen, turbidity, various chemical titrations,
c) supporting equipment such as refrigerator, freezer, autoclave, glassware, chemicals, microscopes, freezer, drying oven, aquaria, (with running seawater where possible), spectrophotometer.

For the Model I curriculum the minimum field experience could be accomplished in one or two days from either a vessel or a shore-based facility. For the Model II curriculum, it would be desirable for students to spend at least one continuous week at sea aboard a vessel appropriately outfitted for oceanographic research. For the Model III curriculum it would be desirable to have 2 to 4 weeks at sea for each student.

d) Teaching Materials

It is expected that each discipline will have access to a collection of resources or teaching aids to illustrate lecture and laboratory presentations: bathymetric maps, sediment/rock/coral collections, biological specimens, current charts and films/slides/videotapes/photographs.

General Aspects of Marine Academic Research

There is a need for practical experience in all three curriculum Models. It reinforces and complements classroom learning and exposes students to current research equipment and methods. The marine science research activities should be conducted in coordination with undergraduate curricula to provide up-to-date information to the students at various levels of the teaching and training programme in marine science.

Indeed, the last level before graduation from a Model III curriculum should emphasize the benefits of research inputs. The research programmes to be designed need not be specific to the first degree in marine science, but some efforts have to be made to adapt the marine science research to any particular situation during the implementation of the teaching and training programmes.

Examples of marine research results could be documented from any marine science research institution throughout the world. This approach should have the advantage of (a) to support the idea that the oceans and the seas are shared by many countries, and (b) not to confine the marine science curricula to local aspects. The research results to support the teaching and training programme for a first degree in marine science should be selected on the basis of both fundamental and applied aspects of marine science.

Curriculum Assessment

A good curriculum aims to produce a well trained person with a inquisitive and explorative mind. The curriculum should emphasize training through research and marine related work experience, because of the importance of this approach in the development of the needed research skills and good work habits. It also provides a motivational tool for the individual to do research in the library, in the field, as well as in the laboratory.

Feedback from graduates on how they have perceived their training and how the training has prepared them well for their current jobs and/or further studies, is very valuable to training institutions and staff concerned with curriculum development. It is also important for universities to get feedback from the employers of marine science graduates as well. The use of feedback in curriculum design, implementaion and evaluation was also recommended in 1982 by the Workshop on Ocean Engineering Teaching at the University Level (Unesco Reports in Marine Science 25, pages 6 to 8).

The results of feedback would, however, need to be very carefully interpreted so as to distinguish misperceptions from real defects in the curriculum. For feedback information to be very useful, the timing of the evaluation of the curriculum is very critical as this would determine the nature of the responses the graduates would give to the questions posed to them. For graduates who do not get jobs in marine science-related fields, it would be interesting if the assessment of the curriculum would also identify transferable knowledge and skills (e.g. familiarity with ecosystem components and processes, application of scientific method, computer use, statistical analyses, laboratory or field protocols, shipboard experience, report writing, problem solving, organization, etc.), that those graduates are employing in their respective jobs.

In order to ensure and to maintain international standards of acceptablility, institutions offering degree programmes in marine science should subject their curricula to external review. This may be achieved either through the appointment of one or more external assessors or by a visiting group who can assess both the curriculum and the facilities available for training. As a part of this assessment process, curricula should be reviewed on a regular and periodic basis by faculty and assessors to ensure that it continues to meet appropriate standards and reflects the training needs of the nation or region.

Summary

On the basis of the results from the global survey of first degree curricula in marine science, three basic curriculum models, related to the traditional branches of oceanography (biological, chemical, geological and physical) are proposed as guidelines on how marine science teaching and training may be offered at the undergraduate level. These models have been devised to take into account the evolutionary perspective of emerging institutions as well as those that already have a solid basis in the field of oceanography:

Model I prescribes the minimal approach required for students who, once engaged in basic science courses, may take elective and introductory courses in the field of oceanography.

Model II has the same philosophy of a major in a basic science but has greater emphasis on the introductory courses in marine science than was proposed in Unesco Technical Paper in Marine Sciences 19 (1974), to incorporate the multi- and interdisciplinary characteristics of oceanography.

Model III is a more advanced curriculum which will lead the student to obtain a B.Sc. or equivalent degree in marine science, with emphasis in one of the main branches of oceanographic science. As in Model II special attention must be given to its multi- and interdisciplinary nature. The practical and technical aspects of oceanography must be stressed in a guided project or thesis. The general topics which must be taught in Model III are similar to those in Unesco Technical Papers in Marine Science 19, while for additional and updated details, a specialist in the particular discipline or subject should be consulted.

Resources required to support each model are generally identified. Feedback from graduates and their employers, in addition to periodic external reviews, are recommended to achieve and maintain programme quality.

ANNEX I

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ANNEX II

Selected workshop presentations to exemplify the development, nature and diversity of instructional marine science programmes at the first degree level.

Example 1 : BRAZIL (p. 23)

Example 2 : CHINA (p. 24)

Example 3 : TANZANIA (p. 29)

Example 4 : THAILAND (p. 32)

Example 5 : UNION OF SOVIET SOCIALIST REPUBLICS (p. 34)

Example 6 : UNITED STATES OF AMERICA (p. 41)

EXAMPLE I : BRAZIL

At the Oceanographic Institute of the University of Sao Paulo (IOUSP), courses in the main classical disciplines of oceanography have been offered since 1971 as electives to undergraduate students of other institutes at the main campus. They include the institutes concerned with the basic sciences (Physics, Mathematics, Biosciences, Chemistry) and the applied sciences (Engineering, Geosciences, Astronomy and Geophysics, Veterinary Medicines and Public Health).

Course offerings increased during the past 15 years, particularly after Unesco Technical Paper in Marine Science 19 was issued in 1974. This same document helped us to plan our graduate curricula in biological and physical oceanography.

Undergraduate courses have also been established in Brazil at the Fundaçao Universidade do Rio Grande and at the Universidade Estadual do Rio de Janeiro. In 1980 a Working Group was created by the Ministry of Education and Culture to implement the following two main points in relation to first degree training:

a) The Career in Oceanography,
b) The Minimum Curriculum in Oceanography.

The Working Group was composed of twelve representatives of the main universities involved in teaching oceanography. After several meetings during the period from 1980 to 1985, a Minimum Curriculum in Oceanography was proposed with the following main objectives:

- An undergraduate course in Oceanography must maintain its interdisciplinary nature.
- The student should receive education in a specific field of Oceanography (Biological, Physical, Geological and Chemical).

To reach these main objectives, the Working Group decided that an undergraduate course in Oceanography, should contain the following three parts:

1st part: Topics in the field of basic sciences (Physics, Mathematics, Chemistry and Biology).
2nd part: Topics in the field of Oceanography, which must focus on the interdisciplinary nature of Oceanography.
3rd part: Topics in the professional specialization of the student with emphasis in Biological, Physical, Chemical or Geological Oceanography.

The number of credit hours in each part must be at least 1750, 1250 and 900 hours, respectively. The first and the second parts are common to all students. Finally, in this Minimum Curriculum special attention is given to the experimental nature of Oceanography. Hence, of the total of 3900 credit hours, 900 hours must be spent in practicals and on board research vessels.

EXAMPLE 2: CHINA

History of Development

In China, the training of marine science students at the first degree level started forty years ago. The first Department of Oceanography was set up in 1946 at Xiamen University on the East China Sea coast when some oceanography scientists returned to China after being abroad during the second world war. In 1952 the university system in China was reorganized and a new Department of Oceanography was established at Shandong University with a part of its teaching staff moved in from Xiamen University. As a result of rapid development, the Department grew into a college in 1959: the Shandong College of Oceanography. In 1970, a new training centre for marine geologists was set up in Shanghai,from which the Department of Marine Geology, Tongji University, evolved.

At present hundreds of undergraduate students in marine science are enrolled in China each year. At least five 'key' universities directly under the National Commission of Education offer first degrees in marine sciences, not including marine-related fields such as fisheries and sea-transportation for which there are several specialized colleges. The largest marine science training institute is the Shandong College of Oceanography located in Qingdao on the Yellow Sea coast. About 600 undergraduate students are enrolled every year in its nine departments, most of which are specialized in marine sciences. The Department of Oceanography in Xiamen and the Department of Marine Geology at Tongji University in Shanghai each enrolls 60-80 undergraduate students per year.

Tracing back the history of training marine scientists in China, we see a process of development quite characteristic of most countries. We started with marine biology, then extended to physical oceanography, or oceanography sensu strictu, and in recent years we have an intensive development in training marine geologists.

A Debate

Despite all the development, a debate has been going on in China for many years: is the first degree appropriate to marine sciences? Or in other words, is the training of marine scientists at first degree level specific enough to establish a department or specialization? An illustration of the various points of discussion in respect of our own Department follows.

Our Department of Marine Geology, Tongji University, Shanghai, was established eleven years ago (in 1975), being required by the rapid development of offshore geological prospecting, mainly for petroleum. Nowadays, it has two undergraduate programmes in "Marine Geology" and "Applied Marine Geophysics", an academic staff of nearly 70 teachers, over 40 postgraduate and about 250 undergraduate students. With its orientation towards offshore prospecting, the department has developed

very rapidly. Regardless of its relatively short history, it became the only one department in our country where all three degrees in marine geology are offered: B.Sc., M.Sc. and Ph.D. (To offer the second and third degrees in China requires the authorization of a governmental committee of high-level scientists).

Nevertheless, since its establishment until the present time, there have always been two opposite opinions concerning the necessity and suitability of such a department with its undergraduate programmes. Some people hold that marine geology as an undergraduate specialization is unnecessary. They believe that a geologist trained in a non-marine oriented department of geology will be perfectly adapted to offshore work just after some three months on-the-job training. In this vein, it is preferred to have, say, a petrographer, a paleontologist or a geochemist, rather than a general marine geologist, as it is much more essential and more difficult to yield good basic knowledge or skills in basic geology and one of its branches, rather than in marine sciences. 'Marine Geology' as a scientific discipline is complementary to 'land geology'. While land geology is now split into so many branches, the same should be for marine geology. Hence, it is unreasonable to train a 'marine geologist' in general without emphasis on one of its branches.

On the other hand, many administrators and scientists believe that first degree marine science training is extremely necessary for China now that the country needs more specialists to allow the rapid development of our offshore activities whether or not in co-operation with overseas companies. Certainly, it would be good if we could train enough postgraduate students in marine geology: but, as in all new fields, it is impossible to have a large number of postgraduates without suitably trained undergraduates. After all, our teaching staff and training centre have to prepare themselves for offering adequate marine geology instruction. A geology teacher can hardly be qualified for training marine geologists if he does not have his own experience in offshore work. In these circumstances it is realistic to begin with offering a first degree curriculum, and at the same time develop the capability to provide second and third degrees in marine geology.

In fact, the establishment of a marine geology department first in Qingdao and then in Shanghai was in conformity with the requirement of the country to speed up the training in marine science and the utilization of marine resources. Our first degree holders have quickly met the need for marine geologists in the country and filled the knowledge gap. They work as investigators on drilling rigs or research vessels, in laboratories or in research centres. Several have obtained high positions; for example, one of our former students is Vice-Director of the Bureau of the Marine Geology Survey. All departments and institutions of the National Bureau of Oceanography have on their staff graduates from the Shangdong College of Oceanography, some in very senior posts. Our offshore work would not be what it is today if there had been no graduates from the relevant marine science departments.

However, the situation is changing now. China reintroduced its degree system in 1978 after thirty years of virtual abondonment. Now both high-level universities (or colleges) and research institutes of the Academia Sinica have their own second and third degree programmes. This is a serious challenge for our first degree students in seeking employment. If positions as university teachers or research scientists

were available several years ago to students with a B.Sc. degree, obtaining such positions now has become very difficult if not impossible. All 'key' universities and most institutions of the Academia Sinica require at least a M.Sc. degree when hiring new staff. Moreover, the vacant posts for marine geologists and geophysists are being filled up, particularly in large cities such as Shanghai, despite of the rapid development of offshore exploration and exploitation. The Ministry of Petroleum still asks from us more graduates, especially geophysists, for oil fields and offshore exploration companies located in remote provinces where our students, unfortunately, do not always like to go.

As a result, we are facing a problem of offering marine-related jobs. In China all graduates from universities are guaranteed jobs by the Government. Hence there is no employment problem for students in this sense. However, some of our graduates are necessarily employed by organizations where no marine geologists or geophysists are requested. In other words, some of our graduates have to work in coastal areas in non-marine related jobs. This is, of course, a very strong argument for those who deny the necessity of maintaining marine geology as a first degree specialization or department.

The problem is not limited to marine geology, and to a certain extent concerns other marine science disciplines as well. There is no doubt that physical oceanography or oceanography s.s., should be an independent specialization, but the number of oceanographers required annually in our country is limited and it becomes difficult to keep a reasonable ratio between the number of students and the number of teaching staff. The viability of a teaching department becomes questionable when the number of students gets lower than a minimum ratio. Hence, the question still remains open whether it is better to have a college or department specialized only in marine disciplines or to train marine scientists in a university or department with a broader spectrum of scientific disciplines?

Comparison with Other Countries

With the above-mentioned problem and debate in mind, we have been trying during the last eight years or so, to compare with, and to learn from, undergraduate programmes in overseas countries.

As a result of our comparison of more than ten countries in terms of training of geologists in general and marine geologists in particular, we found three stages in the training development of marine scientists. At the first stage, when offshore activities and marine science in a country are non-existant or limited, no local marine science training can be offered and marine scientists are trained mostly abroad. At the second stage, when a country starts to develop its marine science and offshore activities, first degree marine science training is required and emphasized. At the third stage, when marine science is highly developed, marine science will be incorporated to a large extent into basic science disciplines, and becomes an essential and integral part thereof. At this stage, the first degree marine science training is reduced to, and designed mainly for, training technical and various kinds of auxiliary staff.

Thus countries with highly developed marine science and offshore activities have relatively few or no first degree programmes that specialize in marine geology, while countries just beginning marine geology work have relatively extensive first degree programmes in marine geology or even special departments. The reason lies in the different degree of incorporation of 'marine science' courses into 'basic science' ones. In industrialized coastal countries, most universities have marine science research and teaching programmes. Consequently, they have percentagewise fewer separate and specialized marine departments than countries just developing their marine activities. An example is the Geological Institute of Kiel University, West Germany, where about two-thirds of the research work is marine oriented and where well-known marine scientists have graduated. But there is neither a specialization called marine geology, nor a department in marine geology, although even such courses as scientific diving and offshore geological mapping are offered. Another example is the Geological Institute of ETH in Zurich. This is again a renowned marine geology research centre where highly qualified students are being prepared, but there is also no department of marine geology.

Admittedly, both examples are taken from a similar educational system in which university training during the first three years or so represents the 'Vordiplom' stage with wide coverage in scientific discipline, but no specialization. It is only during the fourth and fifth years that students do specialize and obtain the so-called 'Diploma'. Hence there is no first degree specialization. However, the incorporation of marine science into basic science is not limited to universities in the two European countries referred to above, but occurs in many countries. Tokyo University, Moscow University, University of Texas at Austin and many others have a marine science institute or school to coordinate marine-related research projects and training programmes between departments, and in some cases to run the ship. Most of the relevant science departments have marine-oriented research projects and staff, but they are not separated from the other (non-marine) part of their discipline. In my opinion, it is a natural tendency for marine science to be incorporated into basic science and to become an essential integral part, when marine science is really grown up. In geology, for example, it is already impossible now to teach geotectonics without plate tectonics and sea-floor spreading, which obviously belong to marine science. It can be predicted that with the rapid development of paleo-oceanography and other new directions related to deep-sea drilling, it will be impossible to teach historical geology without recent advances yielded by deep-sea research. The same is true for sedimentary petrography, and many other study areas. When I asked an old American expert geologist whether or not marine geology should be a specialization for students, he replied, "I would like to have global geology rather than marine geology".

This tendency of incorporating marine into basic science is believed to be growing in the foreseeable future. One of the consequences for basic science of this tendency is the introduction of marine science courses in training programmes for non-marine degrees. The introduction of a marine geology course in the Department of Geology of Beijing University, where no marine geology degree is offered, is a case in point. A similar course has since long been given in the Geology Department of Moscow University. On the other hand, for marine science an unavoidable consequence of the same tendency will be the loss of specialized degree programmes as the marine science is integrated or "dissolved" into basic science, except maybe for physical oceanography.

At Tongji University, for example, we are considering if a major part of the marine geology course can be transferred to other geological disciplines, leaving only a series of lectures on special topics for the course. In this case the proportion of marine science courses in the marine geology curriculum will diminish, but the marine geology teaching at the university as a whole will by no means be reduced.

The development of marine science training in China, is an example of the three-stage process referred to above. The earliest scientists working in marine science, mainly marine biology, appeared in the 20's; they received their professional education mainly overseas. About thirty years later Xiamen University and Shandong University established oceanographic departments, but this was on a small scale. This was the first stage during which modern marine science developed from non-existence into limited activity. In terms of marine geology, training programmes were tried in Shanghai since 1960, but our efforts failed due to the absence of field practice at that time in the country. Only in the 70's when offshore exploration started to develop with the concomitant urgent need for marine geologists and marine geophysicists, was it possible and necessary to establish a department of marine geology in Shanghai. This was the second stage, 'the' time for first degree training in marine science as large numbers of research and teaching positions in the newly established marine institutions, departments and exploration corporations were available to our students. Now more recently, the situation has changed, and we are obviously moving from the second to the third stage when only those with higher degrees will be accepted to work in research and university teaching jobs. For the present a certain amount of first degree holders are still required, especially in offshore oil corporations, as assistants in laboratories or research units and sometimes as university demonstrators.

Since university teaching should be oriented to the future, our training programme must be designed for the 90's and the next century. Therefore we are thinking of broadening the spectrum of marine science teaching by combining marine and non-marine disciplines. As the needs for graduates majoring in marine sciences vary due to many factors, such as oil prices, it seems better to train students with knowledge and skills fitting both marine and non-marine employment. Alternatively, the first degree should be oriented to train technical and auxiliary staff.

EXAMPLE 3: TANZANIA

Aims of the Programme

The rational exploitation of marine resources requires a proper understanding of the nature of the resources, the extent and distribution of their occurrence and the proper technological know-how. In many African coastal states, the teaching of marine science in universities is a recent development and in many of these institutions there are as yet no comprehensive study programmes covering the whole spectrum of marine science at the undergraduate or postgraduate level. The situation with regard to research in marine science is equally unsatisfactory.

Faculties of science in universities have an important role to play in directing teaching and research efforts towards provision of qualified scientific manpower to tackle development problems. The Faculty of Science in the University of Dar-es-Salaam was established in 1965 at a time when there was a great need for science teachers in the country. The character of these early requirements has not changed much over the years. The majority of our students (over 70%) are still trained to become science teachers. The remaining graduate with a general B.Sc. or a B.Sc. in Geology and secure employment in Government ministries, parastatal organizations, research institutes and industry.

From 1975, The Faculty of Science, University of Dar-es-Salaam, has been offering a 3-year B.Sc. degree programme in marine biology and oceanography. This programme was started in response to a request from the Ministry of Natural Resources who wanted to have a cadre of personnel trained at the B.Sc. degree level. Prior to that the highest trained cadre of personnel recruited by the Ministry of Natural Resources for the fishery sector were holders of the Diploma Certificate from the Kunduchi Fisheries Training Institute. To date our B.Sc. degree programme has produced 56 graduates with a marine science background. The University of Dar-es-Salaam recognizes however, that the present programme, details of which are given at the end of this example, clearly need to be improved with the following objectives in mind:

a) To provide students, initially, with a good background in the basic science subjects. The suggested improvements may mean increasing the duration of the programme from the present three to four years.

b) To emphasize the multidisciplinary nature of marine science. The present programme is weak in Physical, Chemical and Geological Oceanography, etc.

c) To emphasize the practical aspects of the training by introducing a dissertation component in the research/project training. This way the graduate will not only acquire adequate field experience but would also have been exposed to a variety of research methodologies and techniques pertinent to his/her area of specialization.

The University of Dar-es-Salaam would also continue to offer the programme for the M.Sc. in Marine Biology and Oceanography as long as there are enough (minimum of 5 per year) qualified sponsored students.

Employment of Graduates

The yearly number of students obtaining the B.Sc. degree with Marine Science at the University of Dar-es-Salaam has essentially remained small between 1977 and 1986, fluctuating from 4 to 10, with an average of 6.5.

As the number of graduates did not exceed 10 per year, the local job market easily absorbed them. For example, the 18 students that graduated in 1977/78, 1981/82 and 1985/86 found employment as teaching staff in the Kunduchi Fisheries Training Institute (5); in the Department of Zoology and Marine Biology, University of Dar-es-Salaam (2); as Research Officer in the Tanzania Fisheries Research Institute (4); in the Division of Fisheries, Ministry of Natural Resources (2); as Regional Fisheries Officer in the same Division (2); and in the Fisheries Project of the Ministry of Defense and National Service (1). (Two women graduates remain temporarily unemployed because they do not want to be posted outside Dar-es-Salaam where their spouses work).

There are as yet no concrete national plans for exploiting the non-living resources of the marine area under the country's jurisdiction. Therefore, it is difficult to know how many marine scientists are required per year in fields like physical, chemical or geological oceanography. The few that are needed at the moment can only find employment in the university.

For the next five years or so graduates of our marine biology and oceanography programme are expected to be largely employed by the following institutions: Ministry of Natural Resources and Tourism, Division of Fisheries (about 5 yearly); Tanzania Fisheries Research Institute with its four research centres (2 to 3 yearly); University of Dar-es-Salaam, Kunduchi Marine Biological Station (1 or 2 yearly); Mbegani Fisheries Development Centre (1 or 2 yearly); University of Dar-es-Salaam, Institute of Marine Sciences in Zanzibar (about 2 yearly); and Ministry of Natural Resources, Fisheries Division, Zanzibar (1 or 2 yearly).

In conclusion, it can be stated that medium-size universities in most coastal countries in Africa have the potential to offer good B.Sc. degree programmes or their equivalent in marine science since supporting departments such as Botany, Chemistry, Geology, Mathematics, Physics and Zoology already exist. However, it usually requires substantial investment in terms of manpower, infrastractural development and equipment to offer strong and well-balanced training programmes in marine science beyond the B.Sc. degree level.

The titles of the courses for the B.Sc. degree with Marine Biology and Oceanography at the University of Dar-es-Salaam, are given here below with the number of course units in parentheses. (one unit is equivalent to 10 lectures or 30 practical hours). For each major subject a variety of courses are offered, including some compulsory core courses and elective or optional courses.

FIRST YEAR

Core Courses (Number of Units)
- Concepts of Ecology (2)
- Introduction to Cell Biology and Genetics (4)
- Chemistry for Biologists (5)
- Animal Kingdom (6)
- Embryology (2)
- Mammalogy (3)

SECOND YEAR

Core Courses
- Ichthyology (3)
- Oceanography (2)
- Practicals in Oceanography (2)
- Primary and Secondary Production (4)
- Freshwater biology (4)
- Phycology I (3)
- Biostatistics (4)

Elective Courses
- Biology of Molluscs (3)
- Field Course in a Fishing Village (2)

THIRD YEAR

Core Courses
- Law of the Sea (2)
- Marine Biology Project (4)
- Benthic Ecology (4)
- Marine Resources (2)
- Sea Fisheries Biology (4)

Elective Courses
- Benthic algal ecology (3)
- Aquaculture (3)
- Estuarine Biology (2)
- Marine Pollution (2)
- Parasitology and diseases in fisheries (2)
- Phytoplankton (2)
- Zooplankton (2)
- Marine Geology (3)
- Marine Chemistry (3)
- Biology of Crustacea (2)
- Marine Microbiology (2)

EXAMPLE 4: THAILAND

Introduction

The interest in marine science education in Thailand began in the early 60's with Professor Dr. Kloom Vajropala, then the Head of the Biology Department of Chulalongkorn University, as the leader. Some marine-related courses like Marine Invertebrate Zoology, Marine Biology, Ichthyology and Oceanography were offered in the Biology Department. In 1966, when chemical oceanography expertise became available, the setting up of a marine science department at Chulalongkorn University was proposed to the Ministry of University Affairs. Two marine science departments were simultaneously set up in 1968, one in the Faculty of Science, Chulalongkorn University, to concentrate on the scientific aspects, and another one in the Faculty of Fisheries, Kasetsart University, to concentrate on fisheries aspects. Both departments were instructed to co-operate closely and to avoid duplications.

At the Department of Marine Science, Chulalongkorn University, two B.Sc. degree options in Marine Science were offered: Marine Biology and Fisheries, and Chemical and Physical Oceanography. (Course titles and credits together with those for similar programmes in other Universities are given at the end). Each year, up to fifteen second year science students are admitted to the Department for a further three years' study. Since 1971 about two hundred students were awarded the B.Sc. degree in Marine Science. In 1973, the Master Degree Programme in Marine Biology and in Chemical and Physical Oceanography was introduced. A Unesco/UNDP project to strengthen the marine science curricula was in operation for five years from 1979. Over fifty graduates have so far obtained their M.Sc. degree in Marine Science. Up to now, this Department is the only place in Southeast Asia offering a degree in the physical and chemical studies of the ocean.

Staff, Facilities, Research

The Department presently has a teaching staff of seventeen which includes 9 marine biologists (3 with Ph.D degrees) 4 marine chemists (all Ph.D) and 4 physicists (1 Ph.D).

At the main campus in Bangkok the facilities are located in the Science Building and include several marine biology laboratories with a small closed sea water circulation system, a clean room and laboratories for bacteriological, geochemical, physical oceanography and aquaculture work. In addition, the Department operates a brackish water station at Ang Sila and has access to the Si Chang Marine Science Research and Training Centre of the University Research Division.

Most of the research activities are multidisciplinary and carried out by the Department's staff and students in co-operation with other university departments or government agencies. Present activities include: estuarine and coastal oceanography, environmental quality and marine pollution impact studies, aquaculture, mangrove and coral reef ecology.

Co-operation

The Department works closely with other departments in the Faculty of Science both in teaching and research. The undergraduate programme relies mainly on courses in the other departments to provide a strong background in basic sciences and mathematics to students. Graduate students also take some courses in the other departments. This interdisciplinary approach is encouraged to further broaden the student's knowledge in related scientific disciplines.

The Department also serves as co-ordinator among government agencies concerned with marine science teaching and research. It has no oceanographic research vessel of its own, but access is ensured through close co-operation with agencies operating such vessels such as the Department of Fisheries, the Hydrographic Office and the Southeast Asian Fisheries Development Centre (SEAFDEC). This arrangement has provided shipboard training and research opportunities for staff and students.

To foster and encourage local research, staff and students are encouraged to interact with scientists in other countries through attendance at scientific meetings, study leave abroad and cooperative research with more experienced foreign scientists, such as through the ASEAN (Association of Southeast Asian Nations) marine science programmes with Australia, Canada and U.S.A.

Course titles and credits of B.Sc. degree programmes at four universities in Thailand:

	Chulalongkorn University		Kasetsart University	Songkhla University	Sri Nakhar University
	Marine Biology & Fish.	Chemical, Physical Oceanogr.	Marine Fisheries	Aquatic Science	Aquatic Science
Maths	12	15	8	8	8
Statistics	4	3	6	3	3
Computer	5	5	-	3	-
Physics	8	14	6	8	8
Chemistry	16	27	17	12	20
Biochem.	4	4	-	4	1
Geology	-	3	-	-	-
Biology	24	8	11	14	27
Aquatic Sci.) Fishery) Aquaculture)	8	-	27	20	21
Mar.Sci.	22	24	15	6	7
Electives	12	13	29	44	22
Special Problems	2	2	-	3	2
Language	9	9	10	9	9
Humanities) Social Sci.)	9	9	9	6	6
Physical Ed.	-	-	2	-	-
	136	136	146	146	140

EXAMPLE 5: UNION OF SOVIET SOCIALIST REPUBLICS

The education system in the USSR can be summarized as follows. Primary and secondary education is compulsory for about ten years from the age of seven. There are three possibilities. The first one is to study in primary and secondary school for ten years; the school leavers obtain a certificate after examination in the main subjects and can continue studying at a "higher school". In the second case, eight years of primary and secondary education are followed by two or three years in a vocational school; after examination one gets the certificate of the secondary school and some professional qualification. The third possibility is to go for four or five years to a tehcnical school, after eight years primary and secondary school education, and to obtain the diploma of the technical school. Some other possibilities also exist, but the three mentioned predominate.

Those with the secondary school-leaving certificate can continue to study at a " higher school" (institutions of higher education). Such studies take five to eight years to complete. During the first two to three years the students usually learn the fundamental (basic) sciences, such as mathematics, physics, chemistry, computer programming, theoretical mechanics, philosophy and others. During the next three to four years, they master their profession and mainly take special courses. Major attention is devoted to practical training; there are different kinds of training in school and industry including independent research and experimental work.

At the final stage the students have to prepare theses or technical projects based on original research. The graduates of the "higher school" gain diplomas, which allow them to take up jobs as scientists, engineers, teachers, etc. or to do further degree studies.

The diploma of the "higher school" signifies a professional qualification approximately equivalent to a master's degree. Our educational system does not have an associate degree or first degree such as a bachelor's. Thus, the diploma of the "higher school", usually obtained around the age of 24, may be considered as the first degree in sciences.

Graduates showing the capability of carrying out research work and wishing to do further degree studies can enter the postgraduate school. After three to four years of study concluded with examinations and the public defence of a thesis at the Scientific Council, students receive the Candidate of Science degree, which is approximately equivalent to a Ph.D. degree. Then, usually after another five to fifteen years of research work, one can make a Doctoral thesis and receive the Doctor of Science degree.

Marine sciences are taught in both technical and higher schools. Higher schools comprise universities, polytechnical and specialized institutions. Universities offer the broad spectrum of basic science disciplines and prepare students mainly for a career as a scientist or teacher. Institutions prepare specialists for the applied fields of sciences. The graduates know rather well one or the other particular speciality, although differences are often insignificant. In

this paper, only university education is considered. Marine science offerings will be illustrated using the example of the Moscow State University, because practically all teaching and training in the marine sciences and marine- related fields are concentrated there, while other universities offer such courses in considerably smaller volume.

Moscow State University, the oldest and largest educational establishment in the U.S.S.R., was founded in 1755. Presently more than 27 thousand students and over 5 thousand postgraduates work in the university. The teaching staff of the Moscow State University consists of eight thousand professors, lecturers and research workers including 130 Academicians and Associate Members of the U.S.S.R. Academy of Sciences, more than one thousand Doctors of Sciences and five thousand Candidates of Science.

The University includes 15 faculties, the Institute of Asian and African Studies and several research institutes. The faculties and institutes consist of 280 departments, 360 laboratories and 11 field stations. Degrees are offered in 46 different subjects. The generalized structure is the university, facilities, departments, and - laboratories.

Marine sciences in the Moscow State University are offered in four faculties: biology, geography, physics, geology. They offer curricula and degrees in marine sciences and degrees with a substantial marine science component. The former include oceanography (Faculty of Geography), physical oceanography (Faculty of Physics), and ichthyology (Faculty of Biology) . The latter include ecology and hydrobiology, and invertebrate zoology (Faculty of Biology), marine geomorphology (Faculty of Geography) and marine geology and geophysics (Faculty of Geology). In addition, there are separate marine courses in the departments of dynamic geology, engineering geology, geochemistry and paleontology (Faculty of Geology); in the departments of economic geography of the U.S.S.R., economic geography of the foreign countries, general physical geography and paleogeography, meteorology and climatology (Faculty of Geography); physics of the earth (Faculty of Physics); physiology of plants (Faculty of Biology); and in other departments.

There are no groups with a special responsibility for coordinating marine science teaching in the Moscow State University. The Scientific Council on "problems of the study of the world ocean" partly performs such duties. It coordinates all scientific research in the field of marine sciences. However, every faculty teaches the marine sciences separately. As a rule, the faculties which offer degrees in marine sciences have several tens of highly trained specialists with good experience in marine research. Every marine science teaching department has five to ten teachers and scientific workers with marine experience. Usually two to five department teachers can instruct the postgraduate students. All the departments in the University offer postgraduate programmes.

Teaching methods in the marine sciences are constantly being improved. Every five years the curricula and course programmes have been significantly changed, new departments opened, and marine field work organized. In recent years a new approach for preparing specialists for the research institutes and industry is applied: some faculties or departments establish contracts for the training of scientists with a marine science institute or marine company as the future employer. The latter can make special demands for graduates, for instance with respect to their ability to use computers, their knowledge and skills in X-ray analysis, shipboard experience, etc. The faculty offers those students individual curricula that fully correspond to the needs of the employer.

There are also other universities that offer degrees in marine sciences and degrees with a substantial marine science component, such as the Leningrad, the Odessa, the Far East, the Irkutsk Universities and some others. References to the degrees offered by these universities are included below.

The Moscow State University offers diploma degrees in oceanography, physical oceanography and ichthyology. Details on the curricula for the three degrees follow.

Diploma Degree in Oceanography

Students in oceanography are trained at the Faculty of Geography; after graduating they receive "Diploma of Oceanographer". This degree was introduced in 1953 for preparing scientists to carry out independent research. Physical oceanography with extensive education in other marine subjects lies at the base of the qualification. The degree studies take five years to complete and are started around the age of 19. The department produces ten to twelve graduates every year.

The following marine science subjects are taught for this degree:

Marine science subjects	Study period in months	Year of subject introduction
Oceanography	24	2
Regional oceanography	8	3
Marine hydrochemistry	8	2
Hydrobiology and marine productivity	4	4
Marine geology	4	4
Navigation for oceanographic research	4	2
Marine hydrological forecasting	4	5

About two-thirds of the total time is devoted to the marine sciences and only one-third to the basic sciences. The basic sciences which are included in the curriculum of this degree are mathematics, physics, computer programming, numerical methods, chemistry, theoretical mechanics, etc. Most of the teachers of the Oceanography Department consider that the study of the marine sciences should begin after two to three year courses in the basic sciences to provide a good basis for the training in marine disciplines and for carrying out independent research later on.

Thesis work is carried out for six months and include independent original research data. The titles of several typical theses prepared during the last few years are :

- The volume-statistics and TS-analysis of Mediterranean water in the Atlantic Ocean.
- Biologically productive areas of the western Indian Ocean.
- Analysis of the meso-scale ocean-atmosphere interaction.
- Nearshore upwelling in the Caspian Sea.
- Satellite information on the ocean surface temperature.

Those with the Diploma of Oceanographer usually get jobs in the research institutes of the U.S.S.R. Academy of Sciences, the Committee for Hydrometeorology and Environmental Monitoring, the Ministry of Fish Industry, the Ministry of Water Economy and of other organizations. The usual occupations are: scientist-probationer, junior research worker and engineer. Practically all graduates with this degree that seek employment enter first jobs that require their marine science knowledge and skills. About half of the graduates work as research scientists, and the other half as marine officers and advisors (40%) and coastal engineers (10%).

All diploma graduates have the possibility to continue studying in order to improve their professional qualifications and skills. More than 80% do so through different courses, scientist exchanges (in the U.S.S.R or abroad) or attending postgraduate courses. The Diploma in Oceanography is also offered at the Leningrad and Simferopol Universities and some institutes.

Diploma Degree in Physical Oceanography

Students in the field of physical oceanography with in-depth knowledge in physics, mathematics, computing technique, etc. are trained at the Department of Marine Physics of the Faculty of Physics. The graduates gain the "Diploma of Physicist" in the field of physical oceanography. This degree was introduced in the Moscow State University in 1947 to respond to increasing requirements of physical oceanographers with high-level theoretical knowledge. Degree studies take five and a half years, and are started at the age of about seventeen. The department produces eight to ten graduates per year.

About 70% of the total time is being devoted to the study of basic sciences, such as general physics, mathematical analysis, thermodynamics, statistical physics, theoretical mechanics, linear algebra, probability theory, equations of mathematical physics and calculus. The following marine science disciplines are taught for this degree:

Marine science subjects	Study Period in months	Year of Subject introduction
Marine dynamics	12	4
Theory of turbulence	8	4
Marine thermics	8	4
Marine acoustics	4	5
Marine optics	4	4
Ocean-atmosphere interaction	4	4
Methods of hydrophysical research	4	4

In addition students receive practical training, among others, aboard research vessels in the Black Sea. They do course work and prepare a thesis. The latter work requiring six months to complete.

The titles of six representative theses prepared recently are listed below :

- Experimental investigations of electro-chemical properties of cold film on the sea-surface.
- Investigation of wind-wave characteristics of the Japan Sea.
- Amplitude fluctuations of sound signals on stationary acoustical tracts in the shallow sea.
- Investigation of the heat-exchange and moisture exchange processes under the conditions of free convection.
- Numerical modelling of temperature and thickness of the upper quasi-homogeneous layer of the ocean.
- Laboratory investigations of wave power action on vertical cylindrical piers.

The graduates usually work in research institutes and laboratories of the U.S.S.R. Academy of Sciences, the Committee for Hydrometeorology and Environmental Monitoring, in the institutions and universities of the Ministry of Higher Education. About 90% of the graduates that seek employment enter marine-related jobs. Approximately 70% of them work as research scientists and 30% as engineers. All graduates wish to do further studies in marine-related sciences; about 60% do enroll for higher degree studies. The others improve their professional qualifications by taking different short courses.

Faculty staff believe that at the early stages of study very limited marine disciplines should be offered. For example, an introductory course on physical oceanography is recommended as it leaves sufficient time for the training in basic sciences which basic sciences which gives the students the possibility to perform better during the second half of the degree studies.

Diploma Degree in Ichthyology

The Faculty of Biology offers the degree in ichthyology. The graduates gain the "Diploma of Biologist-Ichthyologist". This degree was introduced in the Moscow State University in 1940 for preparing highly trained specialists for scientific work and the fishing industry. The degree studies take five years to complete and are usually started at the age of 19 or 20. The Ichthyology Department produces ten to twelve graduates per year.

About one third of the total time required for this degree is devoted to the study of basic sciences, such as mathematics, physics, organic chemistry, analytic chemistry, inorganic chemistry, mathematical statistics, computing technique and programming.

The curriculum of this degree includes the following marine or marine-related disciplines::

Marine science subjects	Study period in months	Year of subject introduction
General Ichthyology	8	3
Particular Icthyology	8	4
Hydrobiology	4	3
Bioproductivity of water masses	4	5
Embryology of fishes	4	4
Principles and methods of studying fish within ecosystems	4	5

The students receive practical training aboard research vessels in the White Sea, and at the biology station. The six-month thesis work commonly includes original observations and interpretations. The titles of typical theses prepared recently are:

- Ichthyoplankton of open sea areas in the north-western Atlantic Ocean.
- Taxonomy and distributions of luminous anchovies.
- Characteristics of migration and orientation of the White Sea cod.
- Mathematical model of the sprat population in the Vistula Bay of the Baltic Sea.
- Comparative characteristics of development of the Far East pilchard and the Pacific smelt.

After obtaining their diploma, graduates work as senior laboratory assistants, scientist-probationers and junior research workers in the research institutes of the Ministry of Fish Industry and the U.S.S.R. Academy of Sciences and Ministry of Water Economy. Some of them become university teachers. About 95% of the graduates take up jobs as scientists and 5% as teachers. All graduates prefer to do further studies and about 80% do register themselves for such studies.

Similar degrees are offered by the Departments of Hydrogeology and Ichthyology of the Leningrad, Irkutsk and Odessa Universities. To prepare a degree proposal for faculty review, a small research project was conducted to discover how other U.S. institutions designed similar curricula (Maynard 1986). The programs at nine colleges and universities were selected based on the criterion that they offered marine-titled baccalaureates in oceanography. The curricula were either in general oceanography (n=4) or in one of the subfields (n=19). Specifically excluded were curricula in marine biology, marine affairs, fisheries, aquaculture, ocean engineering, etc.

There are different opinions concerning early training of students in marine subjects for this degree. Some teachers believe that basic sciences are more important during the first years of study. Others consider that the study of classical mathematics and physics are not relevant for the degree in icthyology. They propose to replace these disciplines by statistics, computing technique and programming. According to their opinion, it would be better to start with marine science offerings at the second, rather than at the third year.

Finally, at the Moscow State as well as at other Universities, degrees with substantial marine science components are offered in ecology and hydrobiology, invertebrate zoology, marine petroleum geology, lithology and marine geology.

EXAMPLE 6: UNITED STATES OF AMERICA

In the U.S.A. undergraduate marine education exists in forms as diverse as the educational institutions which offer baccalaureate degrees. This diversity is underrepresented in the aforementioned global survey, as only ten institutions are included. The 1984 U.S. publication "University Curricula in Oceanography and Related Fields" lists 69 institutions which offer baccalaureates with marine science, another 40 offering degrees in marine science, and 150 institutions offering only undergraduate ocean courses and/or two-year certificates. It is beyond the scope of this presentation to analyze this wealth of offerings. Rather, a case study based at the University of Hawaii will be used to illustrate some aspects of U.S. undergraduate marine science education today.

The University of Hawaii (UH) and most post-secondary U.S. institutions subscribe to the philosophy that an undergraduate major in marine science is inappropriate; only M.S. and Ph.D. degrees are offered by the UH Department of Oceanography. The principal focus for undergraduate ocean education is the Marine Option Program (MOP) which has offered a variety of experimental education opportunities since its inception by the UH Sea Grant College Program in 1971 (Maynard 1984). Students in any discipline from any of the nine campuses in the UH system may enroll in MOP to learn about the ocean through practical experiences such as internships, employment, non-credit courses, workshops, field trips, seminars, and field surveys. Through its newsletter and resource network the program serves as an information clearinghouse for ocean-related activities and jobs. Students may earn a MOP certificate by completing 9 to 15 credits of marine-related courses along with an internship practicum or independent study project under faculty guidance. While this has provided satisfactory enhancement or enrichment for many students, over the years a large number have inquired about majoring in oceanography or marine science at the undergraduate level.

To prepare a degree proposal for faculty review, a small research project was conducted to discover how other U.S. institutions designed similar curricula (Maynard 1986). The programs at nine colleges and universities (1) were selected based on the criterion that they offered marine-titled baccalaureates in oceanography as it is traditionally defined; that is, divided into subfields of biological, chemical, geological and physical oceanography. The curricula were either in general oceanography (n=4) or in one of the subfields (n=19). Specifically excluded were curricula in marine biology, marine affairs, fisheries, aquaculture, ocean engineering, etc.

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(1) Florida Institute of Technology, Humboldt State University, Kutztown University, Long Island University at Southampton, Texas A&M University, University of Alabama, University of Miami, University of South Carolina, University of Washington.

All curricula included Primary Courses (approximately 30 credits) in biology, calculus, physics, and chemistry. Secondary Courses were included in many of the curricula: meteorology, organic chemistry, marine biology, geology, general oceanography, chemical oceanography, statistics, computers and field experience (2.5 credits or more per topic). Overall, each degree required about 30-35 credits in the parent discipline of the subfield (e.g. chemistry), 5-15 credits in the other subfields, and around 30 credits specifically in marine science courses.

To address the criticism that undergraduate marine science curricula are too general or dilute and that they are inadequate preparation for graduate school, ten graduate schools (2) were queried and recommended 28 curricula as appropriate undergraduate preparation for admission to their programs. More than 95% specified chemistry, physics and calculus. About half included biology, additional chemistry, additional physics, geology and geophysics, statistics, and some marine science. By comparing what graduate schools advertised as entrance criteria with what undergraduate marine science curricula included, substantial agreement was discovered among the institutions surveyed. The largest discrepancies were that graduate schools less frequently specified courses in introductory biology and the marine sciences than are usually included in the undergraduate marine science curricula. One is tempted to conclude that the basis for opposition to these degrees is rooted in something other than curriculum composition. The following are possible causes:

a) Most of the senior (i.e. administratively influential) oceanographers today were trained initially in a basic science, and they believe that this is the best way for today's students. Staying within the traditional bounds of each discipline produces the best graduates.

b) The proliferation of marine-labelled courses and degrees in the 1960's and 1970's (partially in response to Cousteau's popularity) led to many offerings of poor quality. This blossoming tarnished the reputations of good degrees and courses (Duxbury 1979).

c) A strong belief prevails that anyone earning a bachelor's degree must qualify for graduate school.

d) Oceanographers perpetuate an elitism, a strong pride, and protectionist territoriality -- they want to make it difficult for others to join their ranks.

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(2) John Hopkins University, Oregon State University, Scripps Institution of Oceanography, State University of New York at Stony Brook, University of Hawaii at Manoa, University of Miami, Univerity of North Carolina at Chapel Hill, University of Rhode Island, University of South Florida, Virginia Institute of Marine Science, Woods Hole Oceanographic Institution.

These reasons are inadequate justification to deny undergraduates access to baccalaureate curricula in marine science, especially in view of the following point:

a) Students should be able to major in fields of study which interest them. It is stimulating and motivational to work with the ocean, especially when field studies are involved. This complements and promotes traditional classroom learning.

b) Marine science has matured to an extent where ocean knowledge can be packaged into coherent and interrelated courses which are easily taught. In addition, the teaching of basic science and mathematics can be illuminated when "marinated" with marine examples.

c) It is important to establish early in an academic career, an overview of oceanography as a science and the ocean as an interconnected system. The early nurturing of integrative thinking processes and the exposure to inter- and multi-disciplinary knowledge, builds skills in problem solving and working in holistic frameworks. This is very different from learning to function within the confines of a single discipline.

d) Students who undertake substantial undergraduate marine science programs have very respectable post-graduation success. From a limited (3) survey of nine institutions (4) offering undergraduate marine degrees, an average of 41% (range=25-55%) of their graduates continued their education in graduate school and a mean of 32% (range=25-46%) obtained marine-related employment. Typical jobs included environmental consultants, aquaria curators, fisheries biologists, aquaculture pond managers, teachers, research technicians, geologists, naturalists, planners, and water quality analysts.

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(3) Most institutions have poor records on the fate of their graduates. Even the better schools have no information on 25-60%. There is a bias towards knowing more about those who stay in the field, than those who transfer to a new one. Statistics are also confounded by graduates who have been out long enough to have had more than one job.

(4) University of California at Santa Barbara, Kutztown University, Roger Williams College, Texas A&M University, University of Hawaii, University of Miami, University of Michigan, University of South Carolina, University of Washington.

Five challenges present themselves for this workshop:

a) Legitimate differences of opinion exist about the "best" design for marine science education at the first degree level.

b) There is no universal solution.

c) A diversity of approaches should be available, including degrees, minors, certificates, etc.

d) Decisions should not be based alone on the labels or titles of degrees or courses. The actual program content must be examined, the learning by students must be evaluated, and the post-graduation "success" should be measured.

e) Resource limitations will restrict what can be offered. All countries need wise development of marine resources and environmental protection - this can be facilitated in part through formal public education at the higher institutions of learning. However, the pursuit of an extensive program in basic ocean research, such as in the U.S.A. is a luxury few can afford. Moreover, not everyone needs to get a Ph.D. in oceanography (even in the U.S.); it is a costly investment of both time and money. The field of oceanography does not need a large number of "Chiefs" and a small number of "Indians".

The development of regional education centers may be considered. The ocean does not recognize political boundaries; studies should be organized along more natural bounds. The needs must also be addressed of students and governments from countries which do not border an ocean. These people have legitimate ocean interests too.

The curriculum content advocated here includes strong basic science and mathematics components, including both multidisciplinary and interdisciplinary elements. Emphasis should be placed on ocean systems within a country's Exclusive Economic Zone (versus the open ocean). Students must also be familiarized with recent technological developments which have greatly influenced our understanding of the ocean: electronics for sampling gear, satellites which give synoptic data over large areas, and computers which enable analysis, manipulation and modelling of large data sets. Classroom experience must be complemented by practical experience - as John Craven always says, working with and thinking about the ocean is very different from dealing with land-based systems - only by first-hand experience can understanding and mastery be gained.

Finally, remember that ocean sciences are rapidly evolving, and an ocean-oriented society is coming. No one can know now, with much accuracy, what employment and education opportunities will be available five years hence to the young person embarking today on a first degree program. Education should provide basic knowledge and tools and an orientation to ocean study. More importantly, the student must know how to think, how to learn, how to pose questions, how to solve problems, and how to adapt to changes.

MARINE SCIENCE CURRICULA FOR RESEARCH AND MANAGEMENT ACTIVITIES CONCERNING THE MARINE ENVIRONMENT

RESPONDANT	
Name	
Address	
Job Title or Position	
Date	

JOB MARKET

Marine Research & Management Activities

ACADEMIC DISCIPLINES

- Mathematics, Basic Sciences: Mathematics; Chemistry; Biology; Physics; Geology
- Additional Requirements in Mathematics and Science: Advanced Mathematics; Statistics; Experimental Design; Computer Science; Assessment Protocols; Meteorology; Pharmacology; Biochemistry; Physiology; Microbiology; Ecology; Taxonomy/Systematics
- Oceanography: Physical; Biological; Chemical; Geological/Geophysical
- Fisheries Biology: General; Management/Population Analysis; Stock Assessment; Aquaculture
- Environmental Studies: Pollution Monitoring; Environmental Analysis; Modelling; Impact Assessment
- Veterinary Science: Parasitology; Virology; Pathology
- Food Technology: Nutrition; Bacteriology; Food Processing
- Ocean Engineering: General; Electronics; Systems; Civil; Mechanical; Mining
- Instrumental Technique: Photography; Remote Sensing; Image Processing; Navigation; Telecommunications; Telemetry
- Field Studies: Dives & Dive Operations; Divers; R.O.V./Submersible; Fishing Gear
- Business Studies: Economics; Commerce; Management & Administration; Planning
- Social Studies: Law of the Sea; Policy Development; Maritime Law; Archeology; Traditional Management
- Geological Exploration: Tectonics & Structural Geology; Geophysics; Stratigraphy/Sedimentology; Petrology/Mineralogy; Physical Geology/Geomorphology
- Others: Seamanship

Mineral & Energy Exploration & Exploration	Hydrocarbons	
	Minerals	
	Energy	
	Water	
Marine Ecosystems	Coral Structure	
	Mangrove Systems	
	Small Island	
	Seagrass Beds	
	Estuaries	
Policy Development	Resource Analysis	
	Law	
	Planning	
Survey & Data Analysis	Cartography/Mapping	
	Remote Sensing	
	Data Management	
Coastal & Nearshore Environment	Enforcement	
	Erosion & Siltation	
	Resource Use/Allocation	
	Ports & Harbors	
	Recreation & Habitation	
	Reclamation	
	Pollution Control	
Human Health	Pharmacology	
	Fish Poisoning/Toxins	
	Marine Infections	
	Bio-active Compounds	
Parks & Conservation Areas	Definition/Law	
	Use/Law Enforcement	
Fisheries (Capture)	Capture	
	Processing	
	Marketing	
Aquaculture & Mariculture	Design/Construction	
	Production	
Biotechnology		
Education & Research	Primary ed.	
	Secondary ed.	
	Tertiary (higher ed.)	
	Research (pure & applied)	
Environmental Forecasting	Meteorology	
	Ocean Conditions	
	Air-sea Interactions	
	Productivity	
	Seismic/Volcanic	

NOTE : CELL ENTRIES ARE 1 = LOW PRIORITY, 2 = MEDIUM PRIORITY AND 3 = HIGH PRIORITY

ANNEX IV

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